PATENT ABSTRACTS OF JAPAN

(11)Publication number : 10-161076

(43)Date of publication of application : 19.06.1998

(51)Int.Cl. G02F 1/09
G02B 27/28

(21)Application number : 08-319777

(22)Date of filing : 29.11.1996

(71)Applicant : FUJITSU LTD

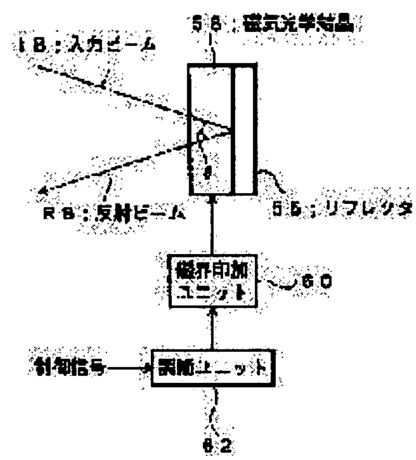
(72)Inventor : FUKUSHIMA NOBUHIRO
ONAKA HIROSHI

(54) OPTICAL DEVICE USING MAGNETOOPTICAL EFFECT

(57)Abstract:

PROBLEM TO BE SOLVED: To obtain an optical device being suitable for miniaturization and low cost conversion by providing a reflector, magnetooptical crystal provided so as to permit an input beam and a reflection beam to pass through, a means for impressing a magnetic field on magnetooptical crystal and the means for changing the magnetic field based on a control signal.

SOLUTION: In a variable Faraday rotary element, the reflector 56 reflects the input beam IB so as to permit it to be the reflection beam RB. Magnetooptical crystal 58 is provided so as to permit the input beam IB and the reflection beam RB to pass through. A magnetic field impressing unit 60 impresses the magnetic field to magnetooptical crystal 58 so as to permit magnetooptical crystal 58 to give a Faraday rotary angle to the input beam IB and the reflection beam RB. An adjusting unit 62 changes the magnetic field to be impressed on magnetooptical crystal 58 by the magnetic field impressing unit 60 based on the control signal. By the configuration, the thickness of magnetooptical crystal 58 for obtaining the required Faraday rotary angle under a given magnetic field condition is made to be a half as compared with the conventional one.



LEGAL STATUS

[Date of request for examination] 18.01.2002

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

CLAIMS

[Claim(s)]
[Claim 1] The optical device equipped with the 1st means for impressing a magnetic field to the reflector which is made to reflect an input beam and is used as a reflective beam, the magneto optics crystal prepared so that the above-mentioned input beam and the above-mentioned reflective beam may pass, and this magneto optics crystal, and the 2nd means for changing the above-mentioned magnetic field based on a control signal.
[Claim 2] The optical device which is an optical device according to claim 1, and was further equipped with the 1st optical fiber for giving the above-mentioned input beam, and the 2nd optical fiber for introducing the above-mentioned reflective beam.
[Claim 3] Are an optical device according to claim 2, and the above 1st and the 2nd optical fiber have the 1st and 2nd excitation edges, respectively. Carry out minute distance alienation and it is located. this -- the 1st and 2nd excitation edges were defined beforehand -- It has further a lens for giving the above-mentioned input beam by collimating substantially the beam emitted from the excitation edge of the above 1st. The above-mentioned reflector is an optical device which it inclines slightly to the above-mentioned input beam and the above-mentioned reflective beam, and the above-mentioned reflective beam is converged with the above-mentioned lens by that cause, and carries out incidence to the excitation edge of the above 2nd.
[Claim 4] The optical device with which it is an optical device according to claim 3, and it is substantially satisfied of d=f-tantheta when setting [the angle which the above-mentioned input beam and the above-mentioned reflective beam make] distance between f, the above 1st, and the 2nd excitation edge to d for the focal distance of theta and the above-mentioned lens.
[Claim 5] two insertion for being an optical device according to claim 2, and inserting the above 1st and the 2nd optical fiber, respectively -- the optical device further equipped with the ferrule which has a hole
[Claim 6] The angle which is an optical device according to claim 1, and the above-mentioned input beam and the above-mentioned reflective beam make is the optical device which is zero substantially and was further equipped with the optical circulator for separating the above-mentioned reflective beam from the above-mentioned input beam.
[Claim 7] It is the optical device which it is an optical device according to claim 1, and the above-mentioned reflector becomes from the reflective film formed on the above-mentioned magneto optics crystal.
[Claim 8] It is the optical device by which it is an optical device according to claim 7, and either N pole of this magnet and the south pole have stuck the 1st means of the above to the above-mentioned reflective film including a magnet.
[Claim 9] It is the optical device which it is an optical device according to claim 7, and the above-mentioned reflective film becomes from a dielectric multilayer.
[Claim 10] It is an optical device containing the 2nd magnet for being an optical device according to claim 1, and impressing the 1st magnet for the 1st means of the above impressing the 1st magnetic field to the above-mentioned magneto optics crystal in the 1st direction, and the 2nd magnetic field to the above-mentioned magneto optics crystal in the 2nd direction in which the 1st directions of the above differ.
[Claim 11] It is the optical device set up so that magnetization of the above-mentioned magneto optics crystal are an optical device according to claim 10, and according [the above 1st and the 2nd magnetic field strength] to the above 1st and the 2nd magnetic field may be saturated.
[Claim 12] It is the optical device in which it is an optical device according to claim 10, the above 1st and the 2nd magnet are a permanent magnet and an electromagnet, respectively, and the 2nd means of the above includes the source of a good transformation style connected to the above-mentioned electromagnet.
[Claim 13] It is the optical device with which are an optical device according to claim 12, and a device and the above 1st and the direction of the 2nd cross at right angles substantially.
[Claim 14] It is the optical device to which it is an optical device according to claim 12, and the above 1st and the 2nd

beam, and the 2nd direction of the above cross at right angles substantially.

[Claim 15] The optical device to which it is an optical device according to claim 14, and the above-mentioned magneto optics crystal gives a Faraday-rotation angle equal to 45 degrees substantially to the above-mentioned input beam and the above-mentioned reflective beam, respectively when the 2nd magnetic field of the above is zero.

[Claim 16] The optical device to which it is an optical device according to claim 14, and the 2nd magnetic field of the above gives a Faraday-rotation angle with the above-mentioned larger magneto optics crystal than 45 degrees substantially to the above-mentioned input beam and the above-mentioned reflective beam, respectively at the time of zero.

[Claim 17] It is the optical device to which it is an optical device according to claim 14, the above-mentioned permanent magnet consists of the 1st permanent magnet which has a flat side, and the 2nd permanent magnet which has opening, the above-mentioned reflector sticks and intervenes between the above-mentioned flat side and the above-mentioned magneto optics crystal, and the above-mentioned input beam and the above-mentioned reflective beam penetrate the above-mentioned opening.

[Claim 18] The 1st optical fiber for being an optical device according to claim 1, having the 1st excitation edge, and giving the above-mentioned input beam, The 2nd optical fiber for having the 2nd excitation edge and introducing the above-mentioned output beam, The optical device to which is further equipped with the lens countered and prepared in the above 1st and the 2nd excitation edge, and the polarizer formed between this lens and the above-mentioned magneto optics crystal, and the attenuation to the above-mentioned input beam of the above-mentioned reflective beam is changed according to the above-mentioned control signal by that cause.

[Claim 19] It is the optical device for which is an optical device according to claim 18, and the above-mentioned polarizer consists of a birefringence wedge board divided into the ordinary ray which spreads an incident beam in the mutually different direction, and an extraordinary ray, and the above-mentioned attenuation stops depending on the polarization state of the above-mentioned input beam by that cause.

[Claim 20] The optical device with which it is an optical device according to claim 19, and it is satisfied of a/f<tanphi when setting [the angle which the above-mentioned ordinary ray and the above-mentioned extraordinary ray make] the focal distance of a and the above-mentioned lens to f for the diameter of the core of phi and the 2nd optical fiber of the above.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] Generally this invention relates to optical devices, such as an optical attenuator using Faraday rotation by the magneto optics crystal, especially about the miniaturization of the optical device which used the magneto-optical effect.
[0002]
[Description of the Prior Art] If a light beam passes through the inside of magneto optics crystals, such as YIG (yttrium iron garnet) placed into the magnetic field, a Faraday-rotation angle will be given to the light beam by the magneto-optical effect according to the thickness of the magnetization magnitude of a vector of a magneto optics crystal, a direction, and a magneto optics crystal. The optical device according to this principle is called a Faraday-rotation child, and the Faraday-rotation child made to impress a magnetic field to a magneto optics crystal with a permanent magnet is put in practical use. Since the magnetization magnitude of a vector and the direction which are given to a magneto optics crystal with a permanent magnet are fixed, in this Faraday-rotation child, its Faraday-rotation angle is eternal.
[0003] The good light variation attenuator including the Faraday-rotation child made to impress a magnetic field to a magneto optics crystal only with one electromagnet is proposed (for example, JP,1-204021,A). However, when only one electromagnet is used, magnetization of a magneto optics crystal is not always saturated. If magnetization of a magneto optics crystal is not saturated, many magnetic domains will arise in a magneto optics crystal. Such existence of many magnetic domains worsens the repeatability of attenuation of an optical attenuator, and though good repeatability is secured, it makes adjustable [of attenuation / continuous] difficult. Moreover, attenuation with difficult control of dispersion of the light in the interface between many magnetic domains is produced.
[0004] By using combining an electromagnet and a permanent magnet, the optical device which made the Faraday-rotation angle adjustable while magnetization of a magneto optics crystal had been saturated is proposed by artificers (157 pp154- OAA and FD9 besides Fukushima, 1996). This optical device is a good light variation attenuator, and the property that attenuation changes continuously to 1.6dB - 25dB is acquired by changing drive current to 0mA - 40mA.
[0005]
[Problem(s) to be Solved by the Invention] The Faraday-rotation child with the above Faraday-rotation angles strange good can apply to the good light variation attenuator for changing the polarization controller for changing a polarization state arbitrarily, and attenuation etc. Since the optical attenuator using the permanent magnet and electromagnet which were mentioned above is offered on the practical scale (30mmx25mmx12mm), it remains as it is and can be included in an optical repeater etc. However, consideration of use of many optical attenuators requires the further miniaturization and low-pricing.
[0006] Therefore, the purpose of this invention is to offer the optical device suitable for a miniaturization and low-pricing. Other purposes of this invention become clear from the following explanation.
[0007]
[Means for Solving the Problem] According to this invention, the optical device equipped with the 1st means for impressing a magnetic field to the reflector which is made to reflect an input beam and is used as a reflective beam, the magneto optics crystal prepared so that the above-mentioned input beam and the above-mentioned reflective beam may pass, and this magneto optics crystal, and the 2nd means for changing the above-mentioned magnetic field based on a control signal is offered.
[0008] In the optical device by this invention, since it is made for a magneto optics crystal to act on the both sides of an input beam and a reflective beam by using a reflector, the thickness or magnetic field strength of a magneto optics crystal for giving a fixed Faraday-rotation angle can be reduced by half.
[0009] Since the magneto optics crystal is generally expensive, reduction of the thickness of a magneto optics crystal is

effective after that the price of an optical device fall. Moreover, reduction of the magnetic field strength demanded is effective because of reduction of the miniaturization of the permanent magnet for impressing a magnetic field to a magneto optics crystal, or an electromagnet, or the drive power of an electromagnet.

[0010]

[Embodiments of the Invention] Hereafter, with reference to an accompanying drawing, the gestalt of desirable operation of this invention is explained in detail. The same sign is substantially given to the same portion through the complete diagram.

[0011] In order to make an understanding of the feature of this invention easy, in advance of explanation of the operation gestalt of this invention, the good light variation attenuator which has the conventional adjustable Faraday-rotation child and it by drawing 1 or drawing 3 is explained.

[0012] Reference of drawing 1 shows the conventional adjustable Faraday-rotation child's 2 perspective diagram. The Faraday-rotation child 2 equips the magneto optics crystal 4, the permanent magnet 6 and electromagnet 8 which impress a magnetic field in the direction which intersects perpendicularly mutually to a magneto optics crystal 4, and the electromagnet 8 with the source 10 of a good transformation style which supplies drive current.

[0013] As a magneto optics crystal 4, YIG started thinly and the 3 (GdBi) 5 (FeAlGa) O12 grade which carried out the epitaxial crystal growth are used. The direction of the magnetic field impressed to a magneto optics crystal 4 with a permanent magnet 6 is parallel to the propagation direction (Z-axis) of the light beam 12 in a magneto optics crystal 4, and the direction of the magnetic field impressed to a magneto optics crystal 4 with an electromagnet 8 is perpendicular to the Z-axis (X-axis). Moreover, the Y-axis perpendicular to the X-axis and the Z-axis is shown.

[0014] The synthetic magnetic field strength by the permanent magnet 6 and the electromagnet 8 is set up as magnetization of a magneto optics crystal 4 is always saturated. Drawing 2 is drawing for explaining the direction and strength of magnetization. [the magnetic field given to a magneto optics crystal 4 in the Faraday-rotation child 2 of drawing 1 , and a magneto optics crystal 4]

[0015] As now shown to a magneto optics crystal 4 by the sign 14 only with a permanent magnet 6, when the magnetic field is impressed, magnetization of a magneto optics crystal 4 becomes the Z-axis and parallel, as a sign 16 shows.

[0016] The impression magnetic field strength at this time (the length of a magnetic field vector 14) is set up so that the intensity of magnetization (the length of the magnetization vector 16) of a magneto optics crystal 4 may be saturated. If it is impressed in parallel with the X-axis as the magnetic field by the electromagnet 8 is shown by the sign 18, a synthetic magnetic field will serve as a synthetic vector of magnetic field vectors 14 and 18, as shown by the sign 20.

[0017] Magnetization as shown in a magneto optics crystal 4 with a sign 22 by this synthetic magnetic field 20 arises. The magnetization vector 22 and the magnetic field vector 20 are parallel, and length's of the magnetization vector 22 correspond with the length of the magnetization vector 16 by the above-mentioned saturation.

[0018] The degree of contribution to the Faraday-rotation angle of the magnetization vectors 16 and 22 is not the same just because the intensity of magnetization of a magneto optics crystal 4 is fixed. It is because it is dependent also on the angle which the direction of magnetization of a Faraday-rotation angle and the propagation direction of a light beam make.

[0019] That is, if the state where the state where magnetization 16 has arisen, and magnetization 22 have arisen is compared, only in the part to which the Z component 24 of magnetization 22 is decreasing to Z component (magnetization 16 itself) of magnetization 16, the latter Faraday-rotation angle will become small. The ratio of the Faraday-rotation angle by magnetization 22 and the Faraday-rotation angle by magnetization 16 is given by cosalpha using the angle alpha which these magnetization vectors make.

[0020] Thus, in the adjustable Faraday-rotation child 2 of drawing 1 , the Faraday-rotation angle given to a light beam 12 can be arbitrarily set up by the source 10 of a good transformation style adjusting the length of a magnetic field vector 18, and changing angle alpha by that cause. Since magnetization of a magneto optics crystal 4 is always saturated, un-arranging [which was mentioned above] of it according to existence of many magnetic domains is lost. The magnetic domain of a magneto optics crystal 4 can understand the state where magnetization of a magneto optics crystal 4 was saturated, as a state set to one.

[0021] Drawing 3 is drawing showing the conventional good light variation attenuator. It is prepared in this sequence from the light source side which an optical fiber 26, a lens 28, the birefringence wedge board 30, the Faraday-rotation child 2 of drawing 1 , the birefringence wedge board 32, a lens 34, and an optical fiber 36 do not illustrate.

[0022] The configuration of the wedge boards 30 and 32 is the same. It is made for the field which the crowning and bottom of the wedge board 30 counter the bottom and crowning of the wedge board 32, respectively, and corresponds to become parallel mutually.

[0023] The optical axis of the wedge boards 30 and 32 is in a flat surface perpendicular to space, and the physical relationship of an optical axis is based on a setup of the loss at the time of the zero input to the Faraday-rotation child's

2 source 10 of a good transformation style. In the following explanation, at the time of a zero input, it supposes that it is determined that loss becomes the minimum, and the optical axis of the wedge board 30 and the optical axis of the wedge board 32 presuppose mutually that it is parallel.

[0024] The light emitted from the excitation edge of an optical fiber 26 is collimated by the lens 28, and becomes an parallel light beam. This beam disregards a beam size and is expressed with the sign 38. A beam 38 is divided into the beam 40 which is equivalent to the ordinary ray (o) in the wedge board 30, and the beam 42 equivalent to an extraordinary ray (e).

[0025] The plane of polarization of a beam 40 and the plane of polarization of a beam 42 lie at right angles mutually. Only the respectively same angle rotates plane of polarization by the Faraday-rotation child 2, and beams 40 and 42 turn into beams 44 and 46, respectively.

[0026] A beam 44 is divided into the beam 48 which is the ordinary ray component, and the beam 50 which is an extraordinary-ray component in the wedge board 32. Moreover, a beam 46 is divided into the beam 52 which is the extraordinary-ray component, and the beam 54 which is an ordinary ray component in the wedge board 32.

[0027] If beams 48, 50, 52, and 54 take into consideration the history of refraction, the configuration of the wedge boards 30 and 32, and arrangement gestalt which have been received, respectively, beams 48 and 52 are mutually parallel, and that of beams 50 and 54 are not mutually parallel. Therefore, only beams 48 and 52 can be narrowed down with a lens 34, and incidence can be carried out to an optical fiber 36.

[0028] The ratio of the total power of beams 48 and 52 and the total power of beams 50 and 54 is dependent on the Faraday-rotation angle in the Faraday-rotation child 2. On the other hand, in the state where the Faraday-rotation child's 2 Faraday-rotation angle is fixed, the total power of beams 48 and 52 is not dependent on the polarization state of the light emitted from the excitation edge of an optical fiber 26. Thus, in the optical attenuator of drawing 3 , attenuation is adjustable electrically and continuously and, moreover, attenuation is not dependent on the polarization state of an input beam.

[0029] Drawing 4 is drawing showing the basic composition of the adjustable Faraday-rotation child by this invention. This Faraday-rotation child has the reflector 56, the magneto optics crystal 58, the magnetic field impression unit 60, and the regulatory unit 62.

[0030] A reflector 56 reflects the input beam IB and is used as the reflective beam RB. The magneto optics crystal 58 is formed so that the input beam IB and the reflective beam RB may pass.

[0031] The magnetic field impression unit 60 impresses a magnetic field to a magneto optics crystal 58 so that a magneto optics crystal 58 may give a Faraday-rotation angle to the input beam IB and the reflective beam RB. A regulatory unit 62 changes the magnetic field which the magnetic field impression unit 60 impresses to a magneto optics crystal 58 based on the given control signal.

[0032] According to this composition, since the input beam IB and the reflective beam RB pass through the inside of a magneto optics crystal 58, the same quantity of a Faraday-rotation angle is substantially given to the input beam IB and the reflective beam RB with the same hand of cut toward the direction of an impression magnetic field. Therefore, thickness of the magneto optics crystal 58 for acquiring a required Faraday-rotation angle can be substantially made into a half compared with the conventional technology under the given magnetic field conditions.

[0033] this invention is not limited by the angle theta which the input beam IB and the reflective beam RB make. In order to separate the reflective beam RB from the input beam IB spatially in this case since the input beam IB and the reflective beams RB overlap mutually in being theta= 0 degree, an optical circulator which is mentioned later is used.

[0034] Use of one common lens which theta is not 0 degree, and it mentions later in order to combine the input beam IB and the reflective beam RB with an optical fiber, respectively in being the small angle of less than 5 degrees is attained.

[0035] In order to combine the input beam IB and the reflective beam RB with an optical fiber, respectively, you may use two or more lenses. Moreover, in order to omit a lens, you may use a reflector 56 as a concave mirror.

[0036] Although a reflector 56 sticks to a magneto optics crystal 58 and is illustrated in drawing 4 , this invention is not limited to this. The optical medium of air and others may intervene between a reflector 56 and a magneto optics crystal 58.

[0037] Drawing 5 is drawing showing the operation gestalt of the adjustable Faraday-rotation child by this invention. Here, the 1st optical fiber 64 for giving the input beam IB and the 2nd optical fiber 66 which should introduce the reflective beam RB are used.

[0038] since [carries out minute distance d alienation and it is made to be located] excitation edge 64A of the 1st optical fiber 64 and excitation edge 66A of the 2nd optical fiber 66 were defined beforehand -- optical fibers 64 and 66 -- a ferrule 68 -- mutual -- parallel insertion -- insertion fixation is carried out at Holes 68A and 68B, respectively

[0039] In order to collimate substantially the conical beam emitted from excitation edge 64A and to obtain the input

beam IB, the excitation edges 64A and 66A are countered, and one common lens 70 is formed.
[0040] Here, the reflector 56 has the flat reflector and this reflector inclines slightly to the input beam IB and the reflective beam RB (a tilt angle theta / 2). When making it the relative location of each element satisfy suitable conditions, the reflective beam RB can be converged with a lens 70, and incidence can be carried out to excitation edge 66A of the 2nd optical fiber 66. This condition is given by d=f-tantheta, when setting [the angle which the input beam IB and the reflective beam RB make] distance between f, excitation edge 64A, and 66A to d for the focal distance of theta and a lens 70.
[0041] two insertion -- since it is established, the manufacturing technology of a ferrule which has a hole can set up correctly the distance between excitation edge 64A and 66A, and can make joint loss small Moreover, since this adjustable Faraday-rotation child can be assembled by adjusting the relative location of a ferrule 68, a lens 70, and a reflector 56, compared with the conventional technology, fabrication operation is easy. A miniaturization and low-pricing are attained by having used the common lens 70.
[0042] Desirably, the magnetic impression unit 60 contains the 1st magnet for impressing the 1st magnetic field to a magneto optics crystal 58 in the 1st direction, and the 2nd magnet for impressing the 2nd magnetic field to a magneto optics crystal 58 in the 1st direction and the 2nd different direction.
[0043] In this case, under the conditions with which magnetization of a magneto optics crystal 58 is saturated, a regulatory unit 62 can change the 1st magnetic field and/or the 2nd magnetic field, and can change a Faraday-rotation angle. Since a magnetic domain is set to one with the saturation of magnetization of a magneto optics crystal 58, while the repeatability of a Faraday-rotation angle becomes good, loss by dispersion becomes small.
[0044] Desirably, the 1st and 2nd magnets are a permanent magnet and an electromagnet, respectively. In this case, a regulatory unit 62 is offered by the source of a good transformation style connected to an electromagnet. Desirably, the direction of the 1st and the 2nd lies at right angles substantially. Thereby, change of a Faraday-rotation angle to unit change of the 1st magnetic field and/or the 2nd magnetic field can be enlarged.
[0045] Drawing 6 is drawing showing other operation gestalten of the adjustable Faraday-rotation child by this invention. Here, a magneto optics crystal 58 is a rectangular parallelepiped configuration arranged along with the X-axis, a Y-axis, and the Z-axis. The X-axis, a Y-axis, and the Z-axis give a 3-dimensional rectangular cross coordinate.
[0046] Moreover, the reflector 56 is offered with the reflective film which consists of a dielectric multilayer formed on the field parallel to XY flat surface of a magneto optics crystal 58. Since a reflective film can be formed thinly, it is suitable for the miniaturization and a dielectric multilayer is easy to manufacture.
[0047] The magnetic field impression unit 60 contains the permanent magnet 72 for impressing a fixed magnetic field to Z shaft orientations, and the electromagnet 74 for impressing an adjustable magnetic field by X shaft orientations at a magneto optics crystal 58 in a magneto optics crystal 58.
[0048] A regulatory unit 62 includes the source 76 of a good transformation style connected to an electromagnet 74. The source 76 of a good transformation style adjusts the current which flows in the coil of an electromagnet 74 based on the control signal given from the outside.
[0049] Especially, with the operation form of drawing 6 , the input beam IB and the reflective beam RB are parallel to the Z-axis, and these overlap mutually. In order to separate the reflective beam RB from the input beam IB, an optical circulator 78 is used.
[0050] The optical circulator 78 has three ports 78A, 78B, and 78C. Incidence of the input beam IB is carried out to this order through Ports 78A and 78B at a magneto optics crystal 58.
[0051] The reflective beam RB from a reflector 56 is outputted to this order through the ports 78B and 78C of an optical isolator 78. Thus, to a reflector 56, the input beam IB and the reflective beam RB are easy for optical-axis adjustment, when perpendicular.
[0052] With the operation form of drawing 6 , the fixed magnetic field by the permanent magnet 72 can be effectively impressed to a magneto optics crystal 58. Contrast with the conventional technology of drawing 1 explains this. Since the practical permanent magnet is opaque, as shown in drawing 1 , it needs two things of a permanent magnet 6 shifted [as opposed to / the beam 12 / very (N pole and south pole)] in the conventional technology. For this reason, magnetic reluctance in the magnetic circuit containing a permanent magnet 6 and a magneto optics crystal 4 cannot become large, and cannot impress the magnetic field by the permanent magnet 6 to a magneto optics crystal 4 effectively.
[0053] On the other hand, with the operation form of drawing 6 , since the both-way beam path by the reflector 56 is formed, magnetic reluctance of the magnetic circuit containing a permanent magnet 72 and a magneto optics crystal 58 can be made small by making the reflector 56 intervene between one pole of a permanent magnet 72, and the end face of a magneto optics crystal 58.
[0054] Thereby, the fixed magnetic field by the permanent magnet 72 can be effectively impressed to a magneto optics crystal 58, and, in addition to the miniaturization of the permanent magnet 72 accompanying the miniaturization of a

magneto optics crystal 58, a permanent magnet 72 can be miniaturized further. Since the thickness of the reflector 56 as a dielectric multilayer is usually several micrometers, the magnetic reluctance can be disregarded as a matter of fact.

[0055] On the other hand, since it is used about the electromagnet 74 in order to impress the magnetic field of X shaft orientations to a magneto optics crystal 58, two poles of an electromagnet 74 can be stuck to two end faces of a magneto optics crystal 58, respectively, and magnetic reluctance of the magnetic circuit containing an electromagnet 74 and a magneto optics crystal 58 can be made small. In drawing 6 , although it is indicated that the air gap is formed between two poles of an electromagnet 74 and magneto optics crystals 58, this is consideration for securing the plainness of a drawing.

[0056] Thus, when making it the input beam IB and the reflective beam RB, and the direction of the magnetic field by the electromagnet 74 cross at right angles substantially, magnetic reluctance decreases and the miniaturization of an electromagnet 74 or reduction of power consumption is attained.

[0057] Drawing 7 is drawing showing the operation gestalt of the good light variation attenuator by this invention. This optical attenuator is characterized as contrasted with the adjustable Faraday-rotation child of drawing 5 in that the polarizer 80 is formed between the lens 70 and the magneto optics crystal 58.

[0058] In this application specification, the word of a "polarizer" is used as the thing which passes alternatively the linearly polarized wave which has the plane of polarization beforehand defined among the supplied light beams, or a thing (polarization beam splitter) divided into two linearly-polarized-wave components which have the plane of polarization which intersects the supplied beam perpendicularly mutually.

[0059] The polarizer 80 of drawing 7 passes alternatively the linearly-polarized-wave component which has plane of polarization parallel to space among the input beams IB. The attenuation determined according to the angle which a Faraday-rotation angle is given twice to this linearly-polarized-wave component by the magneto optics crystal 58, therefore the plane of polarization and space of the reflective beam RB make, and this angle changes according to a control signal.

[0060] The minimum attenuation is obtained when the plane of polarization of the reflective beam RB is parallel to space. When the plane of polarization of the reflective beam RB is perpendicular to space, the greatest attenuation is obtained, and the reflective beam RB does not pass a polarizer 80 theoretically.

[0061] Thus, according to this operation gestalt, offer of the good light variation attenuator to which attenuation can be changed electrically is attained. With the operation gestalt of drawing 7 , since a polarizer 80 passes alternatively the linearly-polarized-wave component which has specific plane of polarization, supposing the Faraday-rotation angle of a magneto optics crystal 58 is being fixed, attenuation will change depending on the polarization state of the input beam IB. That is, the optical attenuator of drawing 7 has the polarization dependency.

[0062] According to this invention, a non-depended polarization good light variation attenuator can also be offered. Hereafter, a non-depended polarization good light variation attenuator is explained. Drawing 8 is drawing showing the operation gestalt of the polarization good light variation attenuator for which it is not depended according to this invention. This operation gestalt is characterized in that the birefringence wedge board 82 is used as a polarizer as contrasted with the optical attenuator of drawing 7 .

[0063] The wedge board 82 is divided into the ordinary ray and extraordinary ray which spread an incident beam in the mutually different direction. A rutile can be used as the quality of the material of the wedge board 82, and about 1 degree can be obtained as a separation angle of an ordinary ray and an extraordinary ray by setting the wedge angle as 4 degrees in this case. In a rutile, the refractive index to an extraordinary ray is larger than the refractive index to an ordinary ray.

[0064] In addition, please care about that 90 degrees of ferrules 68 are rotating to illustration of drawing 7 etc. in drawing 8 . Namely, in drawing 8 , optical fibers 64 and 66 are arranged in the direction perpendicular to space in the ferrule 68 to optical fibers 64 and 66 having arranged in the direction parallel to space in a ferrule 68 in drawing 7 .

[0065] With reference to drawing 9 , operation of the good light variation attenuator of drawing 8 is explained. It is easy to understand that operation of the optical attenuator of drawing 8 assumes the composition turned up about the reflector RP of a reflector 56 as shown in drawing 9 by using the reflector 56.

[0066] In drawing 9 , magneto-optics-crystal 58', wedge board 82', and lens 70' are shown in the symmetric position about Reflector RP, respectively about the magneto optics crystal 58, the wedge board 82, and the lens 70.

[0067] By such assumption, he can understand easily the optical path which results from the 1st optical fiber 64 to the 2nd optical fiber 66. The light emitted from excitation edge 64A of the 1st optical fiber 64 is substantially collimated by the lens 70, and becomes an parallel light beam (input beam). This beam disregards a size and is expressed with the sign 84.

[0068] A beam 84 is divided into the beam 86 which is equivalent to the ordinary ray (o) in the wedge board 82, and

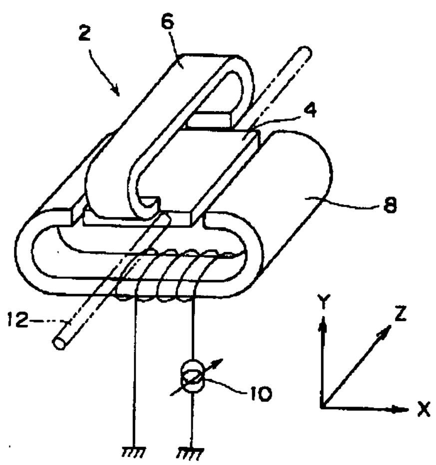
the beam 88 equivalent to an extraordinary ray (e). The plane of polarization of a beam 86 and the plane of polarization of a beam 88 lie at right angles mutually.
[0069] Only the same angle rotates plane of polarization toward the propagation direction, respectively by the magneto optics crystal 58 and 58', and beams 86 and 88 turn into beams 90 and 92, respectively. A beam 90 is divided into the beam 94 which is the extraordinary-ray component, and the beam 96 which is an ordinary ray component in wedge board 82'. A beam 92 is divided into the beam 98 which is the ordinary ray component, and the beam 100 which is an extraordinary-ray component in wedge board 82'.
[0070] A beam 94 receives the refraction as an ordinary ray in the wedge board 82, and is receiving the refraction as an extraordinary ray in wedge board 82'. A beam 96 is receiving the refraction as an ordinary ray in the wedge board 82 and 82', respectively.
[0071] A beam 98 receives the refraction as an extraordinary ray in the wedge board 82, and is receiving the refraction as an ordinary ray in wedge board 82'. A beam 100 is receiving the refraction as an extraordinary ray in the wedge board 82 and 82', respectively.
[0072] Since it is assumed that the wedge board 82 and 82' are the same configurations, beams 94 and 98 are mutually parallel. Therefore, beams 94 and 98 can be narrowed down by lens 70', and incidence can be carried out to excitation edge 66A of the 2nd optical fiber 66. At this time, beams 96 and 100 are not combined with an optical fiber 66 under specific conditions.
[0073] This condition is given by a/f<tanphi, when setting [the separation angle of the wedge board 82] the focal distance of a and a lens 70 to f for the diameter of the core of phi and the 2nd optical fiber 66.
[0074] Now, the ratio of the total power of beams 94 and 98 and the total power of beams 96 and 100 is dependent on the Faraday-rotation angle given by a magneto optics crystal 58 and 58'. On the other hand, when a Faraday-rotation angle is fixed, the total power of beams 94 and 98 is not dependent on the polarization state of the light emitted from the 1st optical fiber 64.
[0075] Therefore, according to this operation gestalt, attenuation can be changed electrically and offer of the optical attenuator for which attenuation moreover does not depend on the polarization state of an input beam is attained.
[0076] In addition, in drawing 9 , illustration of the magnetic field impression unit 60 and a regulatory unit 62 is omitted. Since a beam 86 turns into a beam 96 altogether and a beam 88 turns into a beam 100 altogether when the Faraday-rotation angle of a magneto optics crystal 58 is 0 degree, attenuation serves as the maximum.
[0077] When the Faraday-rotation angle of a magneto optics crystal 58 is 45 degrees, a total Faraday-rotation angle becomes 90 degrees, a beam 86 turns into a beam 94 altogether, a beam 88 turns into a beam 98 altogether, and attenuation serves as the minimum.
[0078] In this operation gestalt, since the minimum attenuation is obtained corresponding to zero current when a magneto optics crystal 58 gives a Faraday-rotation angle equal to 45 degrees substantially when the magnetic field impressed with an electromagnet 74 is zero when the magnetic field impression unit 60 and a regulatory unit 62 as shown in drawing 6 are used, it is convenient practically.
[0079] When the magnetic field by the electromagnet 74 is zero, and making it the Faraday-rotation angle by the magneto optics crystal 58 become a larger value, for example, 50 degrees, than 45 degrees, a bigger dynamic range can be obtained with fewer current.
[0080] According to this operation gestalt, offer of the small good light variation attenuator of polarization distribution is attained. This is explained in contrast with the conventional technology of drawing 3 . In drawing 3 , the beam 48 combined with an optical fiber 36 is receiving the refraction as an ordinary ray in the wedge boards 30 and 32, respectively.
[0081] Moreover, the beam 52 combined with an optical fiber 36 is receiving the refraction as an extraordinary ray in the wedge boards 30 and 32, respectively. Therefore, a time delay may arise between a beam 48 and a beam 52, and polarization distribution may arise.
[0082] On the other hand, with this operation gestalt, since it is as having mentioned above the beam 94 combined with an optical fiber 66, and the history of refraction of 98, delay by refraction is offset and polarization distribution is canceled. Moreover, with this operation gestalt, since the wedge board 82 can be managed with one sheet, a miniaturization, low-pricing, and simplification of fabrication operation are attained.
[0083] Reference of drawing 10 shows other operation gestalten of the magnetic field impression unit 60. Here, as contrasted with the operation gestalt of drawing 6 , two permanent magnets 72A and 72B are used.
[0084] Permanent magnet 72A is the thing of a tabular, and the reflector 56 sticks and intervenes between the flat sides and magneto optics crystals 58 which one of these gives very much (drawing south pole). Permanent magnet 72B has opening and it is made in a circle for the input beam IB and the reflective beam RB to penetrate the opening.
[0085] In order to give an parallel fixed magnetic field substantially to a magneto optics crystal 58 with the input beam

IB and the reflective beam RB with permanent magnets 72A and 72B, the end face corresponding to N pole of permanent magnet 72B has fixed to permanent magnet 72A of a magneto optics crystal 58, and the end face of an opposite side.
[0086] According to this operation gestalt, since a magnetic field can be effectively impressed to a magneto optics crystal 58, this magnetic field impression unit is suitable for the miniaturization.
[0087]
[Effect of the Invention] As explained above, according to this invention, the effect that the miniaturization and low-pricing of an optical attenuator etc. using the magneto-optical effect of an optical device are attained arises, and also there are various effects which were mentioned above.

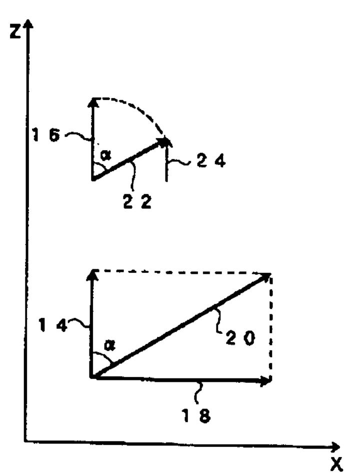
[Translation done.]

DRAWINGS

[Drawing 1]
可変ファラデー回転子（従来技術の）斜視図

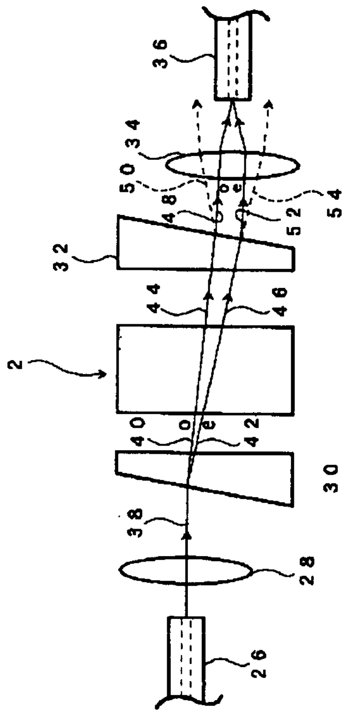


[Drawing 2]
図１の磁気光学結晶における磁界及び磁化の説明図

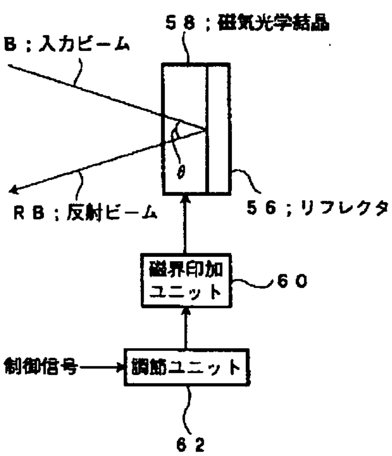


[Drawing 3]

可変光アッテネータ（従来技術）を示す図

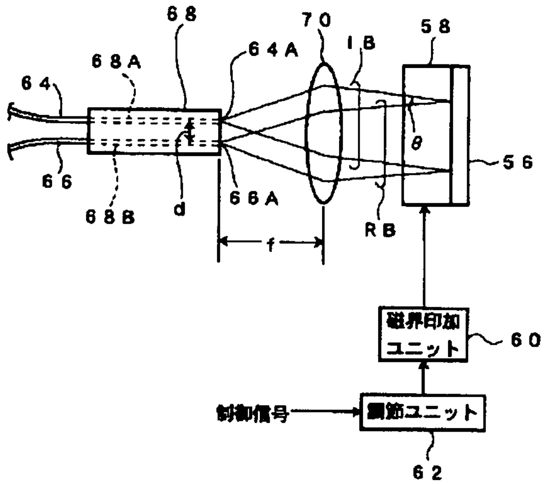


[Drawing 4]
本発明による可変ファラデー回転子の基本構成を示す図



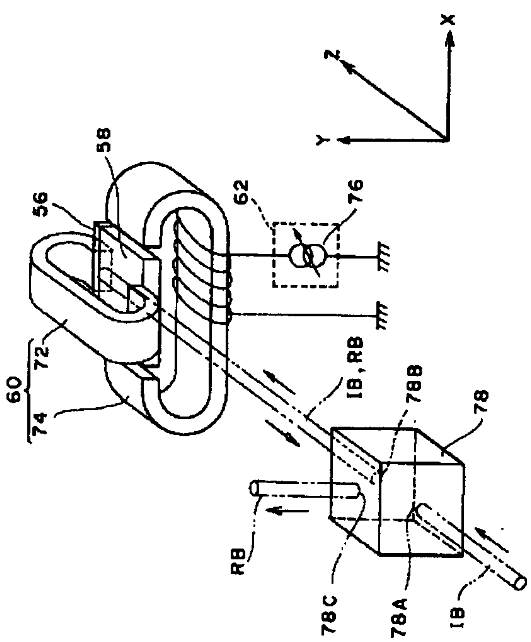
[Drawing 5]

可変ファラデー回転子の実施形態を示す図



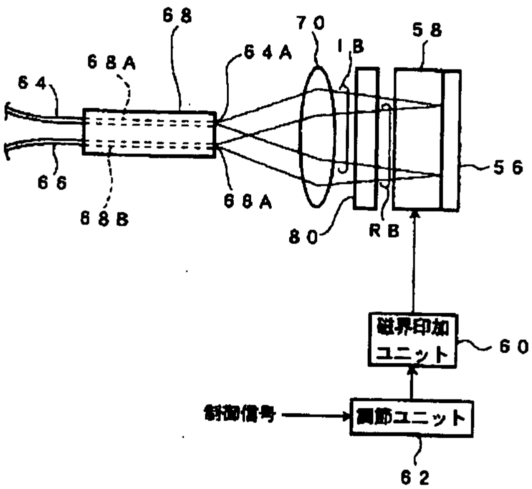
[Drawing 6]

可変ファラデー回転子の他の実施形態を示す図



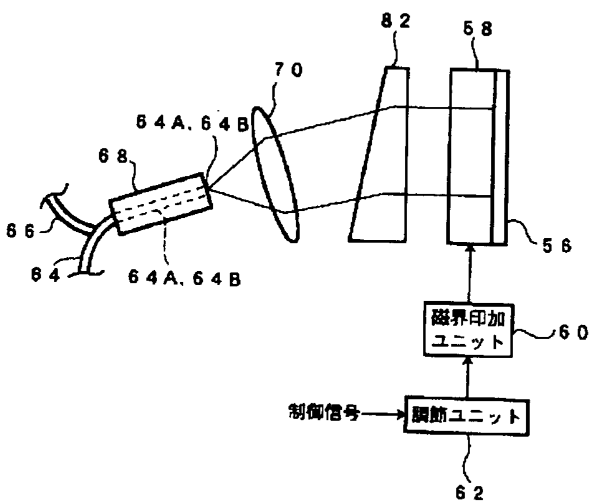
[Drawing 7]

可変アッテネータの実施形態を示す図



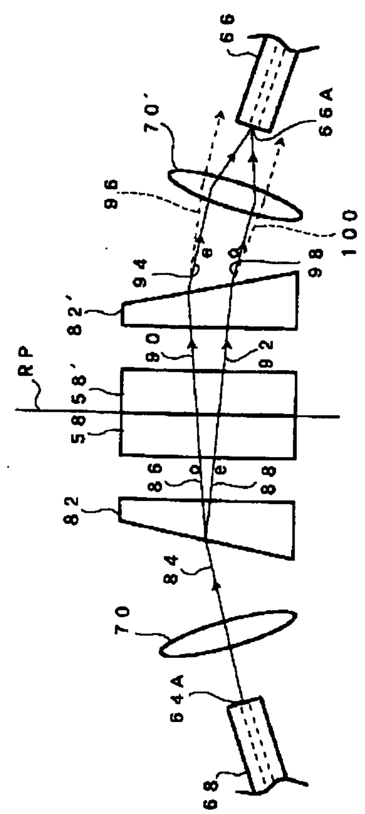
[Drawing 8]

偏波無依存の可変光アッテネータの実施形態を示す図

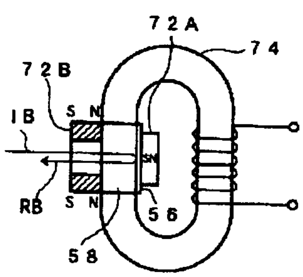


[Drawing 9]

図８の光アッテネータの動作を説明するための図



[Drawing 10]
磁界印加ユニットの他の実施形態を示す図



[Translation done.]